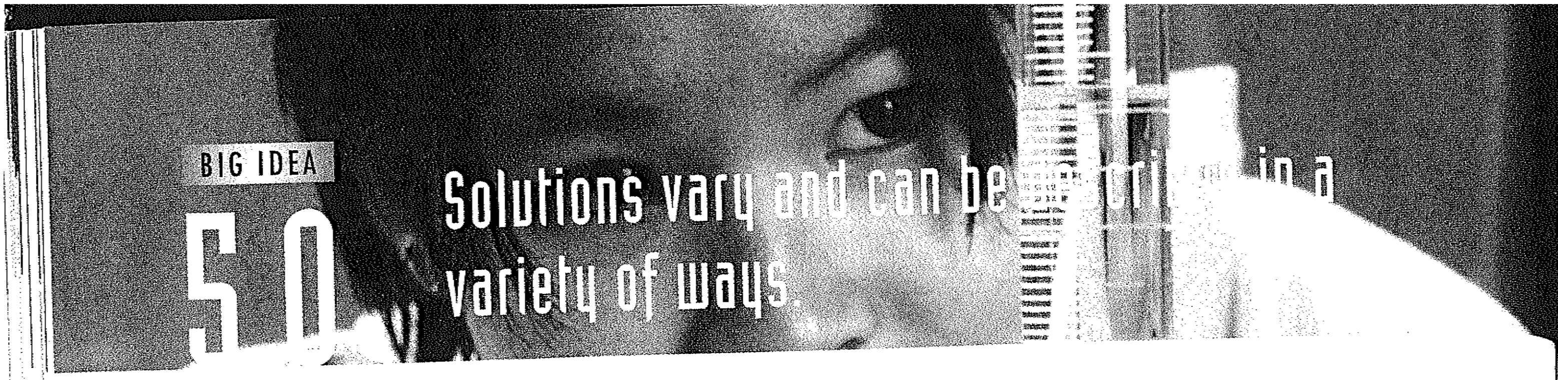
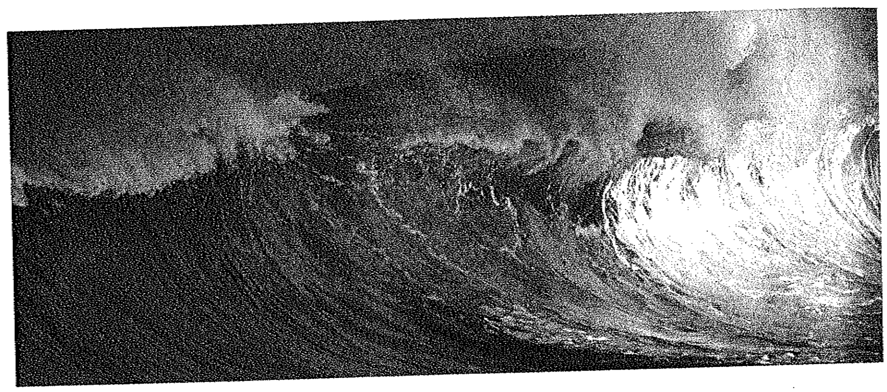


BIG IDEA

5.0 Solutions vary and can be described in a variety of ways.

Solutions can be anything from juice in a glass to water in the ocean. You have learned that when a solute (such as salt) is dissolved in a solvent (such as water), it makes a homogeneous mixture (salt water) called a solution. However, there are other terms that can be used to describe solutions.



5.1 Types of Solutions

Explore

You have probably seen cans of apple juice that say "made from concentrate." But what does that mean? Concentrated apple juice is apple juice that has had most of the water taken out. Any **concentrated solution** contains large amounts of solute in a solvent. Now think of a glass of apple juice to which you have added another glass of water. You have diluted the apple juice. A **dilute solution** has small amounts of solute in a solvent.

*info***BIT**

A dilute solution is one with only a few solute particles compared with the number of solvent particles. Ordinary tap water is a common dilute solution. Can you explain why?

A concentrated solution is one with many solute particles compared with the number of solvent particles. Maple syrup is a concentrated solution. Can you explain why?

Develop

Concentrated and Dilute Solutions

Concentrated and dilute are relative terms. They tell you whether there are small or large amounts of solute in the solvent. But they don't tell you exactly how much solute is in a certain amount of solvent. The **concentration** of a solution tells you the amount of solute (in grams) dissolved in a certain amount of solution. For example, a solution with 50 g of solute dissolved in 100 mL of water is said to have a concentration of 50 g/100 mL of solution. This is read as "fifty grams per one hundred millilitres."

PROBLEM SOLVER

The Tastier Solution

Suppose you were to prepare the following three solutions:

Solution 1 10 g of drink crystals dissolved in 50 mL of water

Solution 2 15 g of drink crystals dissolved in 100 mL of water

Solution 3 6 g of drink crystals dissolved in 25 mL of water

- What is the concentration of each solution?
- Which solution is the sweetest?
- How might the taste of each solution change if you used boiling water, ice-cold water, and lukewarm water? Plan an investigation and carry it out to test your theories.

CAUTION!
Be careful when using boiling water.

unicate

1 What is the difference between a dilute and a concentrated solution?

2 If a solution has a concentration of 50 g of solute per 100 mL of water, what does this mean?

3 Calculate the concentration in grams per 100 mL for the following solutions:

a) 10 g of chocolate powder in 50 mL of water

b) 3 g of sugar in 300 mL of water

c) 5 g of maple syrup in 25 mL of water

reSEARCH

When you buy white sugar, you are really buying sugar crystals. They are made much the same way that the drink crystals you used are made. Basically, a solution of water and a sugar source, which is often sugar cane or beets, is boiled. The crystals that are left behind are what we call "sugar." Research the history and use of sugar.

- How and where was it first made?
- What is the process of sugar-making today?

Sugar cane

try this at **HOME**

Concentrate!

The Question

Are concentration levels the same in similar products?

Procedure

1. Compare the nutrition labels on two different boxes of breakfast cereal.
2. Determine the concentration of fibre in each product.

   Here is how to calculate fibre concentration:

   $$\% \text{ Fibre} = \frac{\text{Fibre per serving (g)}}{\text{Mass of serving (g)}} \times 100$$

3. If you were interested in increasing your daily fibre intake, which cereal would you choose to eat for breakfast? Why?
4. If your doctor has advised you to decrease the amount of sodium (salt) you eat each day, would you still choose the same cereal? Explain.

5.2 Unsaturated and Saturated Solutions

Explore

In addition to "concentrated" and "dilute," there are still other terms that can be used to describe solutions. When you add drink crystals to water, you make an unsaturated solution. An **unsaturated solution** is a solution in which there is still room for more solute to dissolve. What would happen if you kept adding drink crystals? Eventually, no more crystals would dissolve. You would have created a saturated solution. A **saturated solution** is a solution in which no more solute can dissolve.

Develop

Looking at Saturated Solutions

There are many everyday examples of saturated solutions. How many can you list?

Saturated Solutions

The Question

Can you make a saturated solution?

Materials & Equipment

- a graduated cylinder
- a triple beam or an electronic balance
- weighing papers
- water at room temperature
- drink crystals
- beakers
- stir sticks
- hot water

Procedure

1. Measure exactly 50 mL of cold water into a beaker.
2. Accurately measure 5 g of drink crystals. Add the drink crystals to the water.
3. Stir the mixture until the drink crystals have dissolved.
4. Keep adding more drink crystals to the water, 5 g at a time, until no more drink crystals will dissolve.

Keeping Records

5. Determine the total mass of the drink crystals that you added.
6. If you repeated the activity with hot water, would you get the same answer for the saturated solution? Try it!

Analyzing and Interpreting

7. Calculate the concentration of the solution in grams of the drink crystals per 100 mL of water.
8. Did the solution become saturated with the drink crystals? How do you know?
9. Could you dissolve more drink crystals in the hot water?

Forming Conclusions

10. Use the Particle Theory to explain how a solution becomes saturated.

In this last activity, you worked with both unsaturated and saturated solutions. In steps 1 to 3, the drink crystals dissolved easily. The reason is that the solution was unsaturated. As you completed step 4, however, the drink crystals stopped dissolving. The water had dissolved all of the solute it was able to at that temperature and had become saturated.

Communicate

1 What is the difference between a saturated solution and an unsaturated solution?

2 If a saturated solution has a concentration of 20 g per 100 mL of water, how many grams of the solute could be dissolved in 50 mL of water? in 400 mL of water?

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An experiment is considered a **fair test** when only one factor is changed at one time. This changing factor is called an **independent variable.** All other conditions in the experiment must remain the same and are known as **controlled variables**.

For example, imagine you want to find out whether a cookie is better when it is made with butter or when it is made with margarine. You could conduct a fair test by baking two batches of cookies, one with butter and one with margarine. Butter and margarine are your independent variables. Your experiment would not be a fair test if you changed other factors such as the amount of your ingredients or the baking temperature. These are controlled variables.

5.3 Solubility

Explore

What could you do if you wanted to make a solution sweeter, or stronger, or saltier? In the Saturated Solutions Investigator activity, you added drink crystals to water until no more drink crystals would dissolve. You determined the maximum amount of solute (drink crystals) that would dissolve in that amount of the solvent (water). This maximum amount is called the **solubility** of the drink crystals in water at a certain temperature.

The solubility of any solution depends on three factors: the temperature, the type of solvent, and the type of solute. You will now investigate each of these factors.

Develop

Investigating Solubility Factors: Temperature, Type of Solvent, and Type of Solute

Which example do you think will dissolve faster:

- 50 mL of chocolate powder in cold milk?
- 50 mL of chocolate powder in hot milk?

If you said the chocolate powder and hot milk, you're correct, but do you know why? Not all solutes dissolve in solvents in the same way. And like the situation above, the temperature of the solvent has a lot to do with solubility.

PROBLEM SOLVER

Will It Dissolve?

Are some solutes more soluble in water or in oil? Try to dissolve different substances, such as drink crystals, petroleum jelly, sugar, and baking soda, in water and in vegetable oil. Perform "fair tests" to find out which solutes will dissolve in which solvents.

- Was the petroleum jelly more soluble in oil or in water? How do you know?
- Which substances were more soluble in oil? in water? How do you know?
- What did you do to make sure you had a fair test?

In the next activity, you will develop an experiment to measure how temperature affects solubility.

INVESTIGATOR

Temperature and Solubility

Before You Start . . .

You will be working in groups to investigate the solubility of different solutes. Your teacher will assign a chemical to each group. To help you focus on your task, think about what happens when you make hot chocolate. Is the hot chocolate powder more soluble (does it dissolve more easily) in hot water or in cold water? What happens to the movement of particles when they are heated? Will there be room for more solute particles in a heated solution?

continued →

The Question

What effect does the temperature have on the amount of solute that can dissolve in a fixed amount of solvent?

Materials & Equipment

- 2 beakers
- water
- a thermometer
- a hot plate or access to hot water
- chemical—supplied by teacher
- a triple beam or an electronic balance

Procedure

1. Make a hypothesis on how much solute will dissolve in water at room temperature and at 50°C. Remember that you are not investigating *how fast* a solute dissolves, but *how much* solute will dissolve.
   a) What questions are answered by your hypothesis?

2. Decide what materials and equipment you'll need to test your hypothesis.

3. Plan your experiment.
   a) What variable(s) will change?
   b) What variable(s) will stay the same?

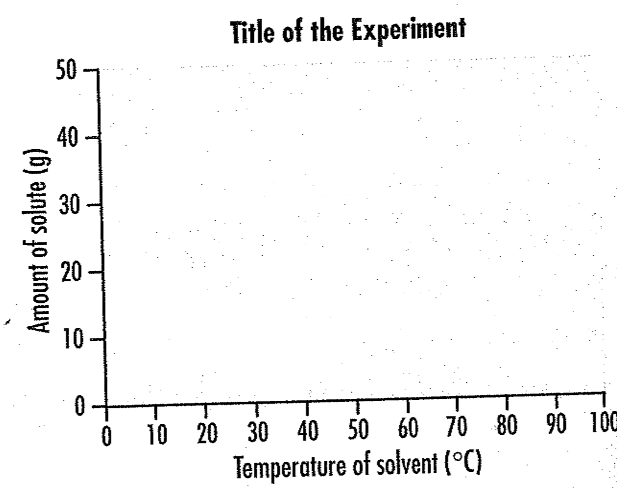
4. Write up your procedure (including safety precautions) and show it to your teacher. Do not proceed until it is approved.

5. Carry out your experiment. Compare your results with your hypothesis. Explain whether you were able to confirm your hypothesis.

Keeping Records

6. You should make sure you have recorded at least the following information: your hypothesis, your procedure, the exact temperature of both liquids, and the mass of solute you added.

7. Make a line graph similar to the one below. Graph the temperature of the liquids you used as well as the amount of solute you added.



Analyzing and Interpreting

8. Share and compare your experimental method and results with those of your classmates. How did your classmates plan their experiments?

9. What variables did each group have to keep the same in order to compare results?

Forming Conclusions

10. In a short paragraph, describe your results and how they compared with your hypothesis.

11. Based on the information in your graph, how much solute do you predict would dissolve in water at 35°C? at 100°C?

Supersaturated Solutions

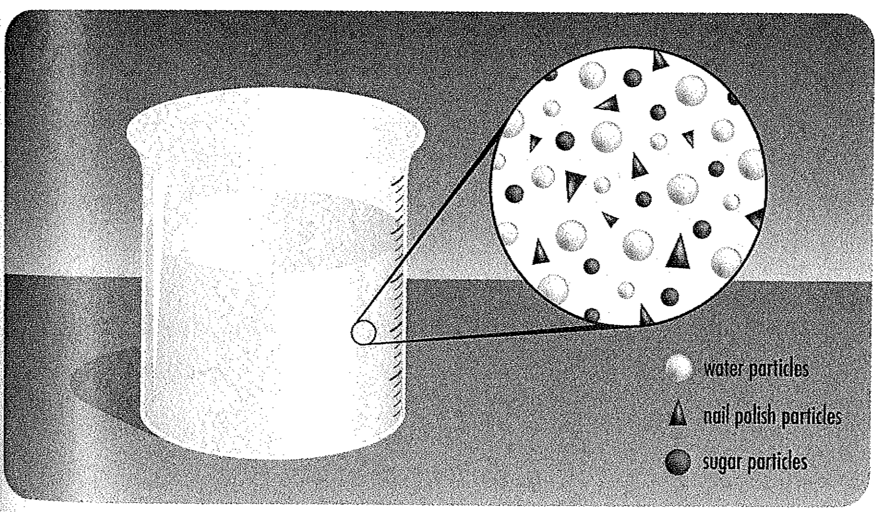
Most solutions can dissolve more solute at higher temperatures. Think about what happens when you add sugar to hot water to make a saturated solution, and then cool it down. What happens to the sugar as the water cools? Try it and see.

Some solutes will stay dissolved in the solution as the solution cools. The cool solution contains more solute than a saturated solution. This solution is called a supersaturated solution. A **supersaturated solution** is a solution that contains more solute than it would normally be able to dissolve at a certain temperature.

Solvent Solubility

Suppose you went into a hardware store and bought a variety of nuts and bolts. When you returned home to put the nuts and bolts together, you found that not all of them would fit. Only those nuts and bolts that were the same size would fit together.

It is the same way with solutes. Some solutes "fit" with the solvent and dissolve. For example, sugar dissolves in water because the sugar particles bind with the water particles. Some solute particles do not bind with the solvent particles. These solutes are labelled as **insoluble**.



Which substance dissolves in water: nail polish or sugar?

In the next activity, you will investigate some solutes that are insoluble in water. You will also see if there are other solvents that will dissolve them.

#12

INVESTIGATOR

Disappearing Nail Polish

The Question

Will a solute that dissolves in water also dissolve in other solvents?

Materials & Equipment

- a test tube
- beakers
- a graduated cylinder
- a sheet of acetate (overhead transparency) or clear Mylar
- cotton swabs
- nail polish
- nail polish remover
- different-coloured markers
- alcohol (ethanol)
- water

CAUTION!
Nail polish remover should be handled with care. Make sure there is good ventilation in your work area. Wash your hands after cleaning up the activity.

Procedure

1. Look at the container of nail polish remover. Discuss the safety warnings.
2. Paint two stripes, about 4 cm long, of nail polish on a plastic sheet and allow them to dry.
3. Add about 2 mL of water to 2 mL of nail polish remover in a test tube.
4. Use cotton swabs to gently rub one stripe of nail polish with water and the other stripe with the nail polish remover mixture. Observe what happens.
5. Use different markers to make a number of lines on a plastic sheet.
6. Using a cotton swab, gently rub the lines with water and then with alcohol. Observe what happens.

Keeping Records

7. Record your observations in a table similar to the one shown below.

Solute	Solvent	Result of mixing

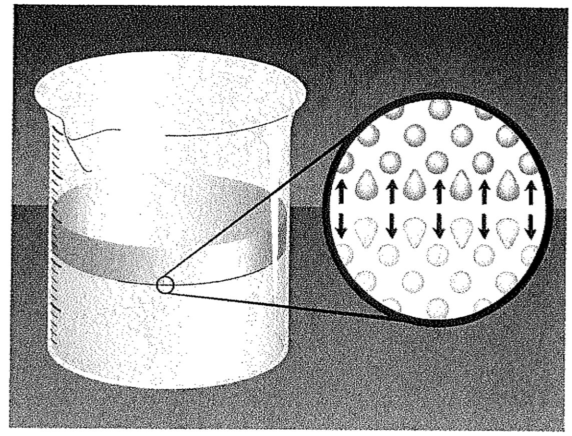
Analyzing and Interpreting

8. What were the safety concerns about the nail polish remover and alcohol?
9. What safety steps were taken for each solvent?
10. What factors had to be kept the same for a fair comparison? How was this done?
11. Did all the solutes dissolve in water? Explain why or why not.

Forming Conclusions

12. Use your results to agree or disagree with the following two statements.
    a) A solute that dissolves in water always dissolves in other solvents.
    b) There are solvents that will dissolve solutes that won't dissolve in water.

In the Disappearing Nail Polish Investigator activity, you discovered that some substances will dissolve in one solvent but not in another. When a substance does not dissolve in another substance, it is because the particles of the first substance do not attract the particles of the second substance. For example, water particles and oil particles do not attract each other. Can you think of other solutes that do not dissolve in water, but will dissolve in other solvents? For example, how do you think you could erase permanent marker from a white board?



An oil and water mixture

Communicate

1 Which of the following combinations will produce a solution?

Solute	Solvent
drink crystals	oil
drink crystals	water
baking soda	oil
petroleum jelly	water
petroleum jelly	oil

2 What three factors affect solubility?

3 Anita makes rock candy by stirring 100 mL of sugar into 50 mL of boiling water. After allowing the mixture to sit for a few days, she noticed that crystals had formed. She collected the crystals with a spoon and washed them with cold water to remove the sticky syrup. Finally, she set them in a warm place to dry. Why did crystals form in Anita's mixture? Explain.

4 Why are some substances insoluble in water? Give an example.

5.4 Solubility and Water Hardness

Explore

When we talk about the type and amount of minerals in water, we say that the water is "hard" or "soft." Calcium and magnesium, minerals that dissolve well in water, tend to make water hard. Hard water has many disadvantages. For example, it can cause a "rock-like" mineral buildup in kettles, dishwashers, and other appliances that use water. It is also difficult to make soap lather in hard water. With soft water, it is very easy to make soapsuds.

#13

Develop

Testing for Water Hardness

In the next activity, you will test the water hardness in your area.

INVESTIGATOR

How Hard is Your Water?

The Question

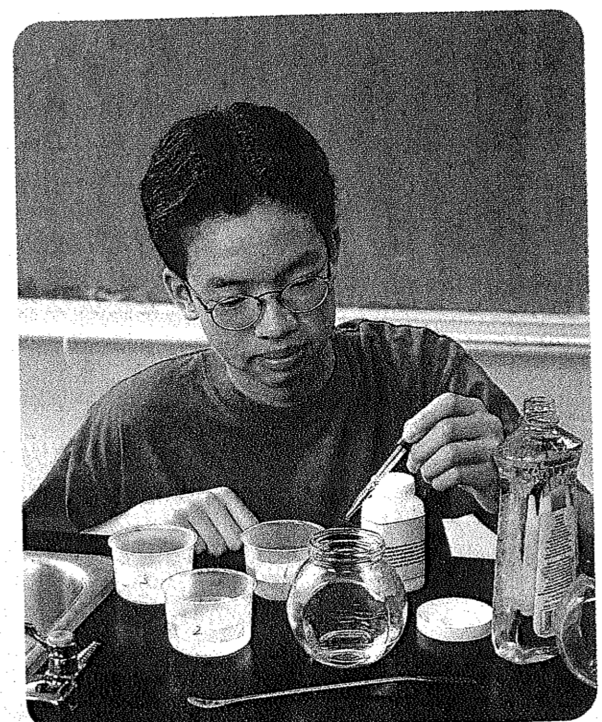
Is your tap water hard?

Materials & Equipment

- tap water
- distilled water
- other water samples (rain, melted snow, etc.)
- a dropper
- liquid soap
- screw-top jars for the water samples
- Epsom salts
- a measuring spoon
- 250 mL beaker

Procedure

1. Pour identical amounts of distilled and tap water and other water samples into each jar.
2. Put one drop of soap solution in the distilled water, screw on the lid, and shake it. Add one drop of soap solution at a time until you make suds. Note how many drops of soap solution you need to make the distilled water sudsy.



3. Repeat the test with tap water and water from other sources.
4. Pour 100 mL of distilled water into a beaker. Add 5 mL of Epsom salts and stir until the salts have dissolved.
5. Add two drops of soap solution to the distilled water and Epsom salts solution and stir. Observe what happens.
6. Repeat steps 4 and 5 using distilled water and 10 mL of Epsom salts.
7. Keep adding additional 5 mL of Epsom salts until you cannot produce suds when you stir.

Keeping Records

8 Record the number of drops of soap solution it takes to make the different water samples produce suds.

9 Compare the amount of suds produced against the amount of Epsom salts added to the distilled water.

Analyzing and Interpreting

10 Is the water in your area hard? How do you know?

11 What effect did the Epsom salts have on the sudsing ability of the soap?

Forming Conclusions

12 How can you make hard water soft? Why would you want to do this?

As you have learned, water that contains a lot of dissolved minerals is referred to as **hard water**. When salt is dissolved in hard water, it creates a solution that helps remove minerals like calcium and magnesium. Without these substances, the water is said to be **soft water**. After these minerals are removed, products like soaps and shampoos dissolve more readily and are easier to rinse away. In many areas of Saskatchewan, people use water softeners to help remove minerals from their water.

infoBIT

First Nations and Métis peoples believe that water is one of the four components of the physical world. All four are alive with a spirit that flows through everything. They believe that humans and water are related through this spirit, and therefore, humans and water have responsibilities to each other. That is the reason many First Nations and Métis peoples believe water to be sacred and that it must be protected and preserved for future generations.

Communicate

1 Explain how you would solve the following problems. Try to give as many possible answers as you can.
a) Your washing machine is producing too many soap bubbles.
b) Every time you wash your hands, there seems to be no way to get all the soap off.
c) The dish detergent you use doesn't seem to make many soap bubbles.

5.5 Check Your Progress

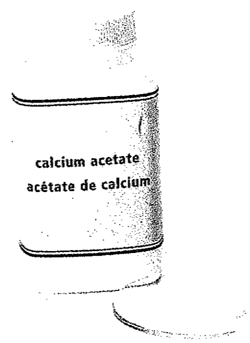
1 Use the Particle Theory to explain what happens to the solubility of a solute as temperature is increased.

2 The Particle Theory says that there are spaces between the particles. What might happen to the spaces as temperature increases? Why?

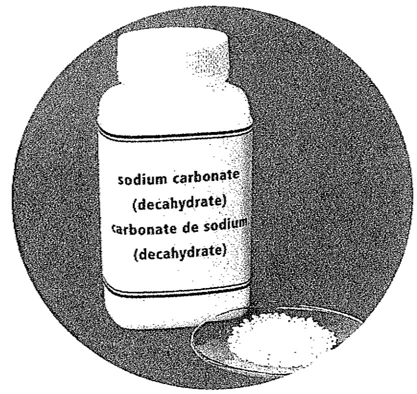
3 For the substances in the table below, answer the following questions.

Solubility in 100 mL of water		
Substance	**at 0°C**	**at 100°C**
sodium chloride	35 g	39 g
calcium acetate	37.4 g	29.7 g
sodium carbonate (decahydrate)	21 g	421 g

sodium chloride



calcium acetate



sodium carbonate (decahydrate)

a) Which substance is the most soluble at 100°C?
b) Which substance is the most soluble at 0°C?
c) Which substance showed the most change in solubility as the temperature increased?
d) According to the table, 421 g of sodium carbonate (decahydrate) would dissolve in 100 mL of water at 100°C. Predict what would happen if you made a saturated solution of sodium carbonate (decahydrate) at 100°C, and then cooled the solution to 0°C.

4 What does insoluble mean? Name some substances that are insoluble in water.

5 Draw a particle sketch comparing what happens when nail polish mixes with water to what happens when nail polish mixes with nail polish remover.

6 Is tap water a pure substance or a mixture? What evidence can you give to support your answer? If you determined that it isn't a pure substance, how could you make it pure?

7 For two samples of water, how would you determine which sample was the hardest?

Careers and Profiles

Nancy Case: A Mechanical Engineer with a Solution

Nancy Case

Anyone who grows up in Saskatchewan has heard of potash. With 10 potash mines producing about 14 million tonnes of potash each year, Saskatchewan is the world's largest potash producer.

One Saskatchewan resident who knows potash first-hand is **Nancy Case**. Nancy is a professional engineer with a degree in Mechanical Engineering. She works at Mosaic Potash Belle Plaine, a potash solution mine located in southern Saskatchewan.

Q: What is your role in solution mining?

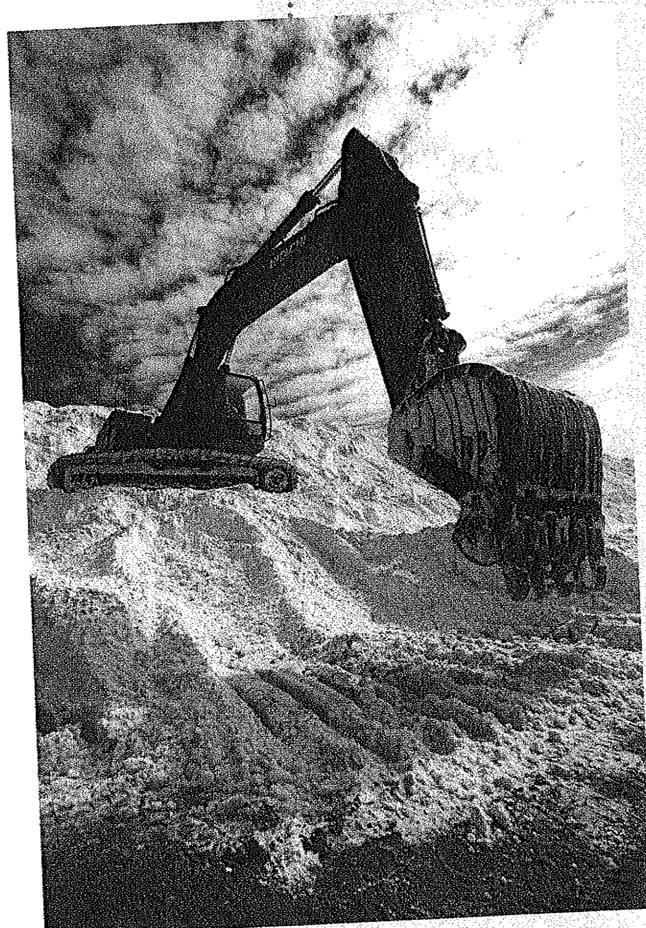
A: My current role is supervisor of the Wet Process Area in the Belle Plaine refinery. I am responsible for taking the potash that has been dissolved underground and putting it through evaporation, crystallization, and drying processes.

Q: Why did you decide on a career in mining?

A: I spent my last summer while in university working at Mosaic in Belle Plaine as an engineering summer student. This was my first experience working in a mine, and I enjoyed the project work I was given. Based on this positive experience, I accepted a process engineering position in the mining department at Belle Plaine the following year. Learning the technical details of solution mining and quickly becoming responsible for the development of underground cavities got me hooked on a career at Mosaic. I have now been with Mosaic for nine years.

Q: Do you have any advice for someone interested in mining as a career?

A: With the world continually requiring more resources, the mining industry is a good choice for a career. There are many diverse career opportunities within the mining industry.



Potash is a mixture of two crystals: potassium chloride (KCl), pictured above, and sodium chloride (NaCl), or common table salt. Its most common use is in the making of fertilizer.